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OBSERVATIONS ON THE MEXICAN FRUIT FLY AND SOME RELATED SPECIES IN CUERNAVACA, MEXICO, IN 1928 AND 1929[1]

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INTRODUCTION

The present studies had their inception in the appearance of the Mexican fruit fly (*Anastrepha ludens* Loew)[2] in the lower Rio Grande Valley of Texas in 1927. Following the discovery, the United States Department of Agriculture and the State authorities adopted an eradication program in Texas, and the Bureau of Entomology undertook an investigation of the insect in Mexico in cooperation with the Mexican Government. The main laboratory has been placed in Mexico City and equipped for investigation of fruit-fly biology under controlled conditions. Studies of the Mexican fruit fly under field conditions were started in a screen insectary in March, 1928, at Cuernavaca, Morelos, in the more tropical district south of Mexico City.

In 1913–14 D. L. Crawford[3] spent a year studying the fruit fly in citrus near Tampico on the Gulf coast, where an average of 5 to 10 per cent of the fruit was infested. In Cuernavaca, however, the most frequent host of *A. ludens* is not citrus but mango, and in the mango more than 90 per cent of the fruit is commonly wormy. Among the dropped fruit gathered, which constituted almost all of the experimental material, not a single uninfested fruit was found. Therefore, Cuernavaca probably presents more nearly optimum environmental conditions for fruit-fly development.

[1] Conducted in cooperation with the Oficina para la Defensa Agricola, Secretaria de Agricultura y Fomento, Mexico. The experimental technic was devised by the senior author, who recorded nearly all the data; most of the experiments were outlined, the data were analyzed, and the manuscript was prepared in its final form by the junior author. The authors are indebted to H. H. Darby for reviewing the manuscript.

[2] Order Diptera, family Trypetidae.

[3] Crawford, D. L. La mosca de la naranja de Mexico, Anastrepha ludens. Rev. Agr. [Mex.] 2:458–462, 1918; 3:174–199, 1921. Reprinted in English, Investigation of Mexican fruit fly (*Anastrepha ludens* Loew) in Mexico, in Calif. Dept. Agr. Mo. Bul. 16:422–445. 1927.

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SEASONAL HISTORY OF THE ANASTREPHA

In Cuernavaca and the surrounding district three species of Anastrepha have been found, each with its characteristic host plant—the Mexican fruit fly (*A. ludens* Loew) in mango (*Mangifera indica*), the Central American fruit fly (*A. striata* Schin.) in guava (*Psidium guajava*), and the West Indian fruit fly (*A. fraterculus* Wied.) in yellow mombin, ciruela, or "plum" (*Spondias mombin*). The fruiting succession and the abundance of these hosts, especially in relation to the rainfall, largely determine the seasonal history of the flies. Accordingly, in November, 1928, the writers placed the original qualitative observations on host-fruit phenology on a systematic periodic basis, using 35 to 38 mango trees, 23 to 28 guava trees, 20 yellow mombin trees, and trees of several other varieties of fruit, and recording for each tree the presence or absence of blossoms and of green, ripe, and fallen fruit. These records were continued for nine months.

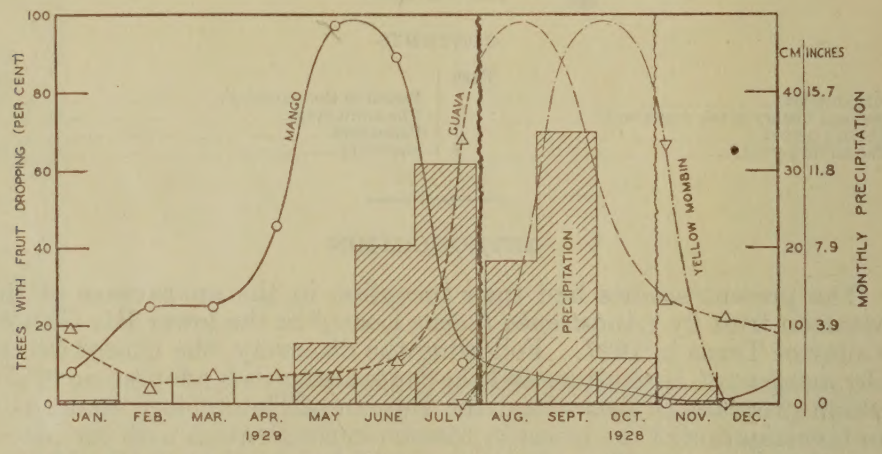

FIGURE 1.—Fruiting sequence of characteristic fruit-fly host plants and precipitation at Cuernavaca, Mexico, in 1928 and 1929. A composite diagram, based on general observations from July 25 to November 5, 1928, and on more detailed records from November 6 to December 31, 1928, and January 1 to July 24, 1929

The results for the characteristic host plants have been plotted on a percentage basis in Figure 1, together with the rainfall during the same period. The curves of the three hosts from July 25 to November 5 are based on general observations in 1928 before regular counts were begun. It is probable that an increase in the number of mango trees under observation would have shown a few with dropping, off-season fruit in November and December, judging from more recent observations by Stone and Darby. The total monthly rainfall is that recorded at the insectary from August 1, 1928, to July 31, 1929. Since records were lacking for the first five days in August, the monthly total has been calculated from the average daily rate for the remainder of the month.

The percentage of trees with falling fruit was adopted as the criterion of host development, because it is after the fruits drop that most of the larvae complete their feeding and enter the soil to form puparia.

The maturing of the larger part of the mango, guava, and yellow-mombin crop during the rainy season was an important factor beneficial to the flies, especially the guava-infesting *A. striata*. De-

spite the continuous supply of food, maintained by means of off-season fruit in April, May, June, and July, it was not unusual to find guavas free of infestation. Infested fruits contained from 1 to 3 larvae each. The infestation built up rapidly during the rainy season and continued to increase after the rains had stopped, reaching its peak in November and December. Very few guavas were uninfested at this season, and the number of larvae in each fruit varied up to 50. The infestation was less pronounced in January; by February it averaged 11.3 larvae in each fruit; and by March only 4.4 larvae in each fruit.

These seasonal changes in the insect population were quite clearly tied up with precipitation, probably through its effect upon humidity. Larvae which in the rainy season would have left the fruit and burrowed into the soil preparatory to puparium formation during the dry season formed puparia inside the fruit. Since the fruit is comparatively small and dries out rapidly, this medium soon became very unfavorable, with the result that many adult flies failed to emerge. The heaviest mortality occurred during November and December. At this time guavas were not abundant for oviposition; yet the adult-fly infestation was the greatest. Many eggs were deposited in each fruit. Larvae developing from these eggs soon consumed all the available food and formed puparia. Premature puparium formation, coupled with the rapid drying of the surrounding seeds, excreta, and other puparia inside any given fruit, resulted in a heavy mortality. As many as 46 dead pupae have been removed from a single guava.

In contrast with that of *A. striata*, the abundance of *A. ludens* was not so directly correlated with the precipitation. The number of larvae in each mango, for example, did not pass through the marked cycle observed in guava. Larvae rarely formed puparia inside the mango, but in the dry season they remained in the larval stage much longer than normally. Yet mortality was above normal, for upon leaving the fruit the larvae often crawled some distance over the surface of the ground before finding a suitable place in which to burrow, being exposed meanwhile to predators, or they burrowed and formed puparia in the moist spot directly under the mango. Frequently the mango was too dry to protect the puparia beneath it from desiccation, especially those formed by the last larvae to leave the fruit.

Rainfall exerted little influence on the reproduction of *A. fraterculus*. Most of the yellow-mombin crop matured and fell to the ground in September and October, during which time soil-moisture conditions were favorable for the pupa. The species was not abundant at any time during the year, and its scarcity was doubtless due to the short, definite season of its host plant. Uninfested yellow mombins were found throughout the fruiting season of the plant; infested fruits contained from one to three larvae each.

In Figure 2 the precipitation at Cuernavaca has been compared with that in Tampico, where Crawford made his studies, and with that in the citrus districts of Texas, Florida, and California. The precipitation in Florida is more similar to that in Cuernavaca than is the precipitation in Texas or California, and should be quite favorable to the fruit fly. Irrigation in the naturally arid States of Texas and California might aid fly survival in those regions.

The temperatures in Cuernavaca were low enough at times to retard the development of immature stages, but they never reached extremes which would influence mortality. In comparison the temperatures in United States citrus regions differed markedly throughout the year. (Fig. 3.) The temperatures in Texas and in Florida during six months rose considerably above those at Cuernavaca, while Tampico, at sea level, was invariably warmer than Cuernavaca, at an elevation of 1,540 meters (5,052 feet).

The marked effect of the fruiting sequence of the typical host upon the seasonal abundance of the different species of Anastrepha was due largely to the minor importance of alternative hosts. As Crawford

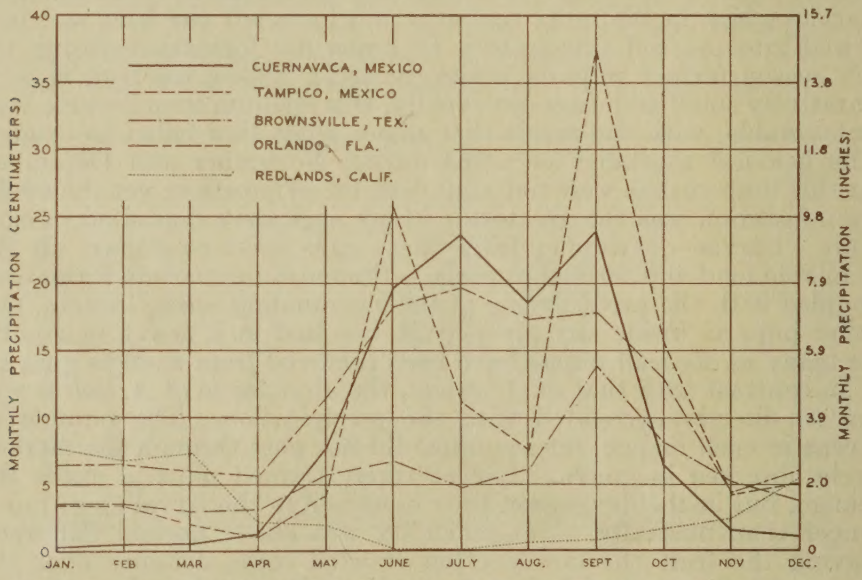

FIGURE 2.—Average monthly precipitation in Cuernavaca and Tampico, Mexico, and in representative citrus districts in the United States. For Cuernavaca the curve averages records for seven to nine years, including 1906–1910 and parts of 1925–1929; for Tampico, Mexico, 1921 through nine months of 1927; for Brownsville, Tex., Orlando, Fla., and Redlands, Calif., the records were from the local stations of the United States Weather Bureau and covered a longer period of years

found with citrus, there were enough off-season mangoes and guavas to carry *A. ludens* and *A. striata* through the year, each on its characteristic host. Most of the mangoes, for example, disappeared by August, but in Borda gardens, where there were many trees, a tree bearing old mangoes heavily infested with maggots and other trees near by with green mangoes nearly large enough for oviposition have been found on the same day in October. The number of adults reared from wormy fruit collected at the end of July, 1928, is shown in Table 1. The number of fruits differed from host to host, depending upon the availability of infested fruits, the mangoes outnumbering all other hosts combined; but since these rearings were not designed to determine host preferences, the number in each lot was not recorded.

TABLE 1.—*Number of flies of Anastrepha ludens, A. striata, and A. fraterculus reared from wormy fruit collected in the field at the end of July, 1928, at Cuernavaca, Mexico*

Fruit	Species of fly	Number of flies
Mango, *Mangifera indica*	*A. ludens*	799
Orange, *Citrus sinensis*	do	22
Sweet lime, *Citrus aurantifolia*	do	12
Peach, *Prunus persica*	do	30
Pomegranate, *Punica granatum*	do	47
Guava, *Psidium guajava*	*A. striata*	73
Yellow mombin, ciruela, or "plum," *Spondias mombin*	*A. fraterculus*	38

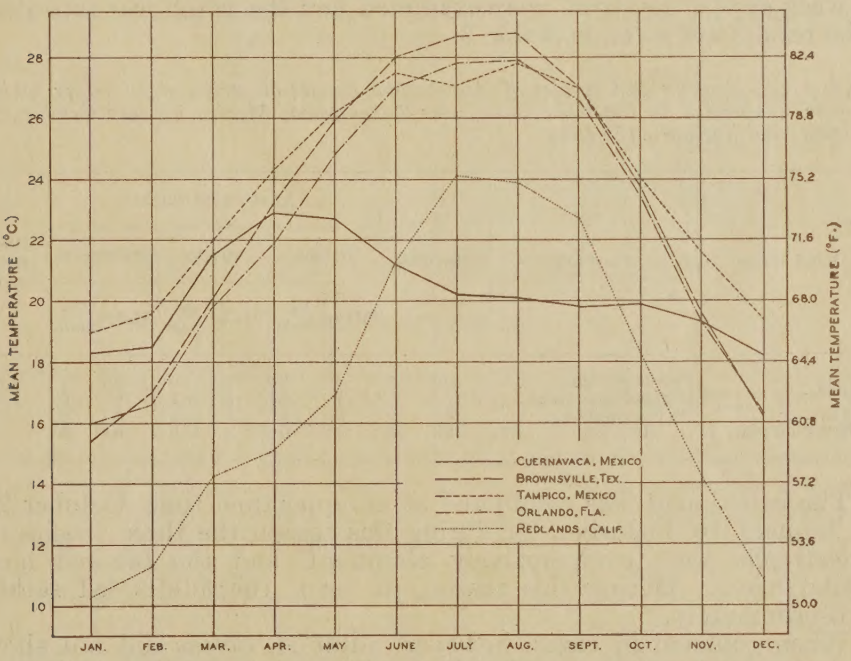

FIGURE 3.—Average monthly mean (or normal) temperature in Cuernavaca, Mexico, and representative citrus districts, based on records of the Weather Bureaus of Mexico and of the United States

The only minor host that could have been of any importance in building up the severe infestation of *A. ludens* at Cuernavaca was sweet lime, which produces fruit throughout the year. It was comparatively infrequent and, since the Mexicans regularly gathered the fruit before it ripened, it probably did not have any appreciable effect on the abundance of *A. ludens* in mango. Pomegranates occurred less frequently than sweet limes, but they ripened at the same season of the year as the mangoes when allowed to remain on the trees. Peaches and oranges were even less abundant, and were gathered unripe, in the same way as the sweet limes. The few oranges grown in Cuernavaca were not badly infested, although old inhabitants say that 20 years ago there were no worms in the mangoes but many in the oranges.

Although mango, guava, and yellow mombin were infested in this region, each by its characteristic species of Anastrepha, a few individuals of other species have been reared by the senior author and by Kapp and Darby from field-collected material. Thus from mangoes they have bred specimens of *A. striata* and from guavas specimens of *A. ludens* and of *A. fraterculus*. Most of these exceptions, however, occurred at seasons when the typical host was much less abundant than that in which the exception occurred.

Flies reared from field-collected fruits indicated a high specific preference for certain hosts for oviposition, but for feeding they were not so exclusive. Strips of sticky fly paper 24 inches long and 1¾ inches wide were suspended in the characteristic host trees. After a week or two the strips were examined and the catch was recorded. The results are given in Table 2.

TABLE 2.—*Number and species of Anastrepha caught on strips of fly paper which were suspended in the trees in or near Cuernavaca, Mexico, between October 29, 1928, and January 15, 1929*

Kind of tree	Location	Strips	Trees	Anastrepha caught						Other flies caught
				ludens		striata		fraterculus		
				Male	Female	Male	Female	Male	Female	
Mango	Borda gardens	20	4	4	6	6	9	0	1	95
	Chapultepec Road	11	2	7	1	5	2	0	0	35
Guava	Borda gardens	15	5	3	1	8	2	0	0	21
Yellow mombin	do	16	4	4	0	3	0	0	0	38

The experiment was conducted at an opportune time, October 29 to January 15, inclusive, for during this season the three species of Anastrepha were comparatively abundant, and the favored host fruits scarce. During this season, at least, the adults fed rather indiscriminately.

When confined in cages, however, adult *A. ludens* did not show exclusive host reactions, either in feeding or in oviposition. Beginning May 27, 1928, more than 18 adults were confined in a netting-covered cage having a capacity of 3½ cubic feet; mangoes, oranges, and guavas were introduced, in pieces for food and whole for oviposition; and the number of flies on each type of fruit was recorded frequently throughout the day. There was no consistent diurnal fluctuation in oviposition, but feeding was more general in the morning (from 6 to 10 a. m., 46 per cent), light in midday (from 10 a. m. to 2 p. m., 18 per cent), and a little heavier in the afternoon until dark (from 2 to 8 p. m., 36 per cent). The relative numbers for the entire day are given in Table 3. While preferring mango, the flies oviposited frequently upon guava under cage conditions; but since these cage conditions were not satisfactory for oviposition, chiefly because of the competition between females and the differences in the amount of fruit surface exposed, it can not be concluded that they oviposit normally in guava. Under cage conditions the preference for ripe fruit for food was well marked, as is shown in Table 4; however, the choice of green fruit for oviposition was even more distinct.

TABLE 3.—*Distribution of adult Anastrepha ludens on different fruits and sugar solution on the basis of the number feeding on pieces of each variety and also of those ovipositing on whole fruits of each variety, Cuernavaca, Mexico, 1928*

Fruit	Flies feeding on pieces of fruit [1]	Flies ovipositing in whole fruit [2]
	Per cent	*Per cent*
Mango	46.2	55.9
Orange	25.5	24.7
Guava	25.3	19.4
Sugar solution	3.0	----------

[1] Number of observations, 340.

[2] Number of observations, 427.

TABLE 4.—*Percentage choice of adult Anastrepha ludens for ripe and green fruits in large cage, Cuernavaca, Mexico, 1928*

Condition of fruit	For feeding		For oviposition	
	Mango [1]	Guava [2]	Mango [3]	Guava [4]
	Per cent	*Per cent*	*Per cent*	*Per cent*
Green	15.9±2.5	26.7±5.8	95.0±2.0	92.9±2.3
Ripe	84.1±2.5	73.3±5.8	5.0±2.0	7.1±2.3

[1] Number of cases, 376.

[2] Number of cases, 247.

[3] Number of cases, 148.

[4] Number of cases, 84.

THE EGG PERIOD

Normally the egg period is spent just beneath the rind of the host fruit. In fruits with thick rinds, such as the grapefruit, it may be spent in the rind. In these experiments, however, the eggs were transferred, just prior to hatching, from the host to a moist chamber which would permit observation. Heavy laboratory watch glasses proved satisfactory for this purpose. A small mound of paraffin was fastened in the center of each dish, covered with black photographic paper, and surrounded with water. Eggs could easily be observed against the black background. The hatch was determined by examining the water for young larvae and checking the number found against the number of eggshells on the support in the center.

The duration of the egg stage depended primarily upon temperature. The relation of length of the egg stage to average daily mean temperature has been recorded in Table 5 and plotted in Figure 4.

TABLE 5.—*Number of individual eggs of Anastrepha ludens hatching in specified number of days in outdoor insectary at indicated average daily mean temperatures, Cuernavaca, Mexico, 1928 and 1929*

Number of days in egg stage	Number of eggs hatching at mean temperature of—								Total number of eggs
	67.3° F. (19.6° C.)	69.1° F. (20.6° C.)	70.7° F. (21.5° C.)	71.6° F. (22.0° C.)	72.5° F. (22.5° C.)	73.4° F. (23.0° C.)	74.3° F. (23.5° C.)	75.2° F. (24.0° C.)	
12	0	0	0	0	1	0	0	0	1
11	0	1	0	2	0	0	0	0	3
10	2	6	1	11	2	0	0	0	22
9	10	0	7	6	8	6	13	2	52
8	5	4	49	34	58	75	24	57	306
7	0	0	63	11	122	595	94	93	978
6	0	0	0	1	18	106	118	125	368
Total	17	11	120	65	209	782	249	277	1,730

Crawford [4] found that the development of eggs deposited in green citrus fruits "may be retarded as much as one month." Though the eggs in the present experiments were deposited in green mango and the juice exuding from oviposition punctures of these green fruits was very irritating or toxic to the adult females, the eggs themselves hatched equally soon whether left in the mango or removed immediately to a moist chamber.

A large percentage of the eggs laid failed to hatch; these will be considered in connection with oviposition.

THE LARVAL PERIOD

The length of the larval period depended not only upon the length of time required for feeding and development but also upon the environmental factors that were operative when the larva reached maturity. Puparium formation apparently could be delayed for a considerable time. Experiments were of two types—those with newly hatched larvae to determine the length of the stage, and those with field-collected full-grown larvae to isolate the factors required for puparium formation.

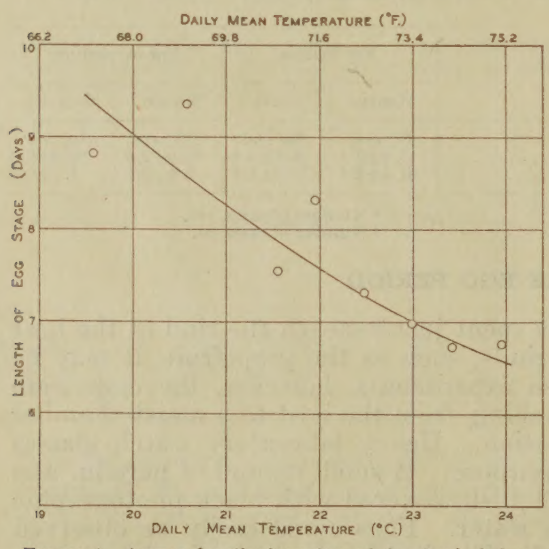

FIGURE 4.—Average length of egg stage of *Anastrepha ludens* in 1928 and 1929 at Cuernavaca, Mexico, plotted against daily mean temperature in the insectary

Newly hatched larvae were reared in heavy laboratory watch glasses and fed with small pieces of fresh mango, renewed every other day. When the larvae were nearly full grown, earth for puparium formation was introduced as well as food. When this technic was used, 16 larvae completed their development and formed puparia. They required from 18.5 to 35 days to develop, averaging 25.2 ± 0.8 days, during the period from June 4 to July 21, 1928 (mean temperature, 70.5° F. or 21.4° C.). How closely this figure applies under field conditions is problematic. Normally food conditions in the field were quite different. As the larvae fed inside the fruit, the media changed continually, not only from the usual ripening processes hastened by the infestation but also as a direct result of larval activity. In the experimental cultures, on the other hand, larvae were fed upon small pieces of fresh mango, renewed too frequently to simulate the cycle in field infestations. A high mortality was further indication that the experimental conditions were abnormal. The younger larvae were especially susceptible, for more than two-thirds of the fatalities occurred during the first four days after hatching.

[4] CRAWFORD, D. L. Op. cit.

The maximum period for reared larvae compared favorably with emergence records from field-collected infested fruit. From mangoes collected on June 8, 1928, larvae continued to emerge for 41 days, at the end of which time three fruits still contained live maggots. From mangoes gathered on August 8 larvae were still emerging 44 days later. The age of these larvae when the fruit was collected is unknown. It is possible that they were then in the egg stage. If so, the maximum egg and larval periods at this season of approximately 45 days for reared material agreed roughly with the 41 and 44 day maxima from these field-collected infested fruits. However, it is probable that these periods could be lengthened further, for when old infested fruit of no apparent food value was opened the contained larvae frequently appeared to be aestivating.

Within the maximum period inside the fruit, provisionally determined as above, environmental factors seemed to control the age at which larvae left the fruit and formed puparia after they were full grown. Some of these factors were independent of the surface upon which the infested mangoes were placed; others acted through the substratum upon the larvae. The fluctuations in the number of larvae leaving the fruit from hour to hour and from day to day were of the first type. Between April 19 and May 4, 1928, of 1,032 larvae emerging from infested mangoes, more than 92 per cent came out before 9 a. m. These mangoes were kept in the insectary, but the same condition was observed outdoors. Diurnal fluctuations of this type have been observed frequently; their cause is obscure.

The rate at which the temperature rose in the morning proved to be a minor factor. Judging from a correlation study covering 34 days, it accounted for less than 10 per cent of the variation in the percentage of each day's emergence which appeared before 8 a. m.

The total number of larvae emerging from a single collection of mangoes varied considerably from day to day. In only two lots out of eight was any age trend apparent. In the other six lots more larvae seemed to emerge after cool nights than after warm ones. Since for these lots, representing mangoes gathered in all seasons of the year, the average minimum temperature ranged from 56.5° to 63.3° F. (13.6° to 17.4° C.), and the average daily emergence from 12.7 to 100.4 larvae, temperatures were expressed in terms of the deviation from the group average and emergence as the ratio of each day's total to the group mean. In this way all lots could be combined in a single correlation table. The correlation coefficient based on the emergence of 5,124 larvae during 109 days was 0.26 ± 0.06.

A preliminary test of the action of temperature on larval emergence gave similar results. A small copper box containing 10 infested mangoes was suspended over a cake of ice for three hours. During this time the temperature inside the box dropped slowly from 71.6° to 53.6° F. (22° to 12° C.), while outside temperature rose from 71.6° to 75.2° F. (22° to 24° C.). Meanwhile 61 larvae emerged, comprising 61.4 per cent of the total number of living maggots in the fruit. No larvae emerged from a check lot of fruit under outdoor conditions.

Rainfall stimulated emergence to a marked degree. From a lot of 120 infested mangoes collected on August 17, 1928, and kept out of doors, the only maggots emerging prior to August 24 were 77 individuals which left the fruit at the time of a rain of 0.77 inch between

8 and 11 p. m. on August 19. At this time there was no emergence from other infested fruit that was protected from the rain. Time of day did not seem to influence the effectiveness of rain in stimulating emergence, for tests conducted in the morning and in the afternoon gave similar results. In these experiments only full-grown larvae emerged, but some full-grown larvae remained in the fruits. By keeping infested mangoes without soil in a dry place, emergence could be retarded without impairing larval activity inside the fruit. Falling water drove out most of these larvae. Thirty infested fruits which had been kept under unfavorable emergence conditions for 20 days were exposed for 10 minutes to a hard, beating rain of 0.22 inch. Out of 293 larvae, 238 emerged. There was no emergence from a check on the inside of the insectary. In a second test 30 mangoes which had been kept for 12 days in a dry place without soil were exposed for 30 minutes to water falling from a shower bath. At the end of 5 minutes 112 larvae had emerged and 25 minutes later 67 more, leaving only 56 maggots in the fruit. Probably it was the mechanical beating of the rain upon the infested mangoes which caused the larvae within to emerge, since the same effect could be obtained by shaking infested fruits. On July 2, 1929, 30 mangoes collected in the field on June 30 were shaken continuously for 15 minutes; 142 larvae, comprising 35 per cent of the total, emerged.

Under the repeated exposures of almost daily rains, the period of emergence from infested mangoes was reduced materially. Two hundred fruits, nearly ready to drop, were picked from the tree on July 8, 1929, and divided into two lots of 100 each. One lot was placed on soil in the insectary and the other on soil outside the insectary. Beginning July 19, 25 fruits from each lot were examined at 6-day intervals to count the number of larvae that had not yet emerged. The results are given in Table 6. The time required to reach 90 per cent emergence from the date the mangoes were picked was approximately 12 days for the exposed mangoes and 25 days for the protected ones. Since fruits exposed to rain decayed much faster than protected fruits, some of this difference may have been due to a higher mortality of the younger larvae in the rain-beaten mangoes. While rain hastened emergence from the fruit and consequent puparium formation, it may also have reduced the number surviving.

TABLE 6.—*Effect of rainfall on the period of emergence of larvae of Anastrepha ludens from infested mangoes collected on July 8, 1929, Cuernavaca, Mexico*

Date of examination	Larvae in protected fruits	Larvae in exposed fruits	Total rainfall July 8 to date of examination
	Number	*Number*	*Inches*
July 19	956	129	4.95
July 25	200	9	6.55
July 31	175	11	9.55
Aug. 7	26	0	9.83

The rate of emergence from infested fruits depended also upon the suitability of the substratum for puparium formation. The emergence holes were usually on the lower side of the fruit, so that larvae starting to emerge would encounter the substratum immediately.

When conditions were unfavorable, fewer larvae emerged. Thirty infested mangoes were transferred daily in the late afternoon, a time when there was little or no emergence, from wet sand to dry sand and vice versa. The emergence results are given in Table 7, lot No. 1. Of the 591 larvae emerging, 70 per cent left the fruit when over wet sand and only 30 per cent on dry sand. From a duplicate series (Table 7, lot No. 2) in which the dry sand was replaced by wire screen, 57 per cent of the larvae emerged on wet sand.

TABLE 7.—*Emergence of larvae of Anastrepha ludens from two lots of 30 infested mangoes each, one transferred daily from wet sand to dry sand or vice versa, the other from wet sand to wire screen, Cuernavaca, Mexico, 1929*

Lot No.	Substratum	Number of larvae emerging on—																	Total number of larvae emerged
		June—									July—								
		22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	
1	Wet sand	17		1		82		14		112		31		50		78		28		413
	Dry sand		5		0		2		84		6		7		55		17		2	178
2	Wet sand	14		2		19		2		17		41		13		106		12		226
	Wire screen		5		1		4		30		17		6		90		6		12	171

The absence of moist soil not only retarded normal emergence from the fruit but delayed puparium formation by full-grown larvae that had been cut from fruit. Larvae were classified as to size and put in Petri dishes with small pieces of ripe mango, one series with soil and the other without. Those on soil burrowed and formed puparia in 0.40 ± 0.27 day in the case of larvae 1.16 cm long, and in 1.20 ± 0.25 days in the case of larvae 1 cm long. Equivalent larvae without soil formed puparia in 13.0 ± 1.5 days and 15.8 ± 1.6 days, respectively.

Preliminary "larval-choice" experiments were run with individual larvae that had emerged from mangoes placed over wire screen. From 14 to 24 (total, 124) larvae were distributed in the center of each of six Petri dishes, each offering an equal choice of sand moistened to two different percentages of saturation. Only one response was clear-cut; any degree of moisture was preferred to a dry medium, 20 larvae burrowing on the moist side (containing about one-third the amount of water the sand would hold) and only 1 in the dry half, and this one died within 24 hours without forming a puparium. With sand containing from 10 to 100 per cent of the total water it could hold, no preferences were apparent. The osmotic pressure of the soil water did not seem to influence either the place where the larvae burrowed or the rate of puparium formation, so far as could be judged from preliminary tests with sand moistened in solutions of dextrose, sucrose, and ammonium sulphate. The osmotic pressure of the sugar solutions varied from 27 to 78 mm of mercury. In burrowing, larvae avoided contact with the transparent sides of a container and usually oriented themselves so that the final position of the puparium was with the head end pointing toward the surface.

Larval mortality under field conditions was not studied specifically. Among individuals large enough to be readily visible to the unaided eye, it was very small. Usually, when death occurred in an infested mango, 100 per cent of the larvae died. In a few cases all the larvae on one side of the mango were dead while all on the other side were alive, but the living and dead larvae were separated by intact pulp.

Both Doctor Darby and the senior author have observed a greater frequency of mangoes containing dead larvae in the rainy than in the dry season.

PERIOD IN THE PUPARIUM

Development within the puparium was studied principally in respect to its length at different seasons of the year. The prepupal and pupal periods, which occur within the puparial case, have not been separated, so the records refer to the combined length of the two stages of development, called the puparial stage.

The length of the puparial period depended primarily upon temperature. From April 28 to December 26, 1928, the average daily mean temperature for 1,246 puparia which transformed within this interval varied only 9.9° F. (5.5° C.), from 64.2° to 74.1° F. (17.9° to 23.4° C.), but the length of the period of development ranged from 19 to 36 days. The correlation of duration of the period and average daily mean temperature for this series is given in Table 8.

TABLE 8.—*Number of individual Anastrepha ludens completing puparial stage in specified number of days at indicated average mean daily temperatures, Cuernavaca, Mexico, 1928 and 1929*

Days in puparial stage	Number of A. ludens completing puparial stage							
	1928							
	64.6° F. (18.1° C.)	64.9° F. (18.3° C.)	68.2° F. (20.1° C.)	68.7° F. (20.4° C.)	71.8° F. (22.1° C.)	73.0° F. (22.8° C.)	74.1° F. (23.4° C.)	Total
36	1	0	0	0	0	0	0	1
35	1	0	0	0	0	0	0	1
34	0	0	0	0	0	0	0	0
33	27	0	0	0	0	0	0	27
32	56	5	0	0	0	0	0	61
31	63	11	0	0	0	0	0	74
30	10	25	0	0	0	0	0	35
29	4	1	2	0	0	0	0	7
28	0	0	16	0	0	0	0	16
27	0	0	159	1	0	0	0	160
26	0	0	521	10	0	0	0	531
25	0	0	158	25	0	0	0	183
24	0	0	22	17	0	0	0	39
23	0	0	4	1	7	0	0	12
22	0	0	1	0	9	0	0	10
21	0	0	0	0	0	29	6	35
20	0	0	0	0	0	42	8	50
19	0	0	0	0	0	4	0	4
Total	162	42	883	54	16	75	14	1,246

Days in puparial stage	Number of A. ludens completing puparial stage				
	1929				
	68.0° F. (20.0° C.)	68.7° F. (20.4° C.)	69.8° F. (21.0° C.)	70.7° F.) (21.5° C.	Total
34	0	1	0	0	1
33	2	1	0	0	3
32	6	2	0	0	8
31	35	4	0	0	39
30	99	20	0	0	119
29	109	128	4	0	241
28	26	161	5	1	193
27	3	34	18	6	61
26	0	13	35	20	68
25	0	1	25	27	53
24	0	0	0	6	6
23	0	0	0	1	1
Total	280	365	87	61	793

From January 4 to March 5, 1929, the development of 793 more individuals was recorded, and these data have also been correlated with the average daily mean temperature in Table 8. The two sets of records have been plotted separately in Figure 5. Although each group was self-consistent, there was about three days' difference between them at a given temperature. No certain explanation for this discrepancy is available. H. H. Darby has collected larvae throughout the year at Cuernavaca and timed puparial development under controlled conditions without finding any seasonal differences.[5] Accordingly, larval food could not have caused the variation noted here. Variations in the daily range in temperature roughly paralleled the discrepancies between the two seasons. The mean temperature for the 30 days from September 3 to October 2, 1928 (exclusive of September 24), averaged 68.0° F. (20.0° C.); from January 11 to February 9, 1929, it also averaged 68.0° F. The daily temperature range was 14.0° F. (7.8° C.) in 1928 and 27.2° F. (15.1° C.) in 1929. The duration of the puparial stage averaged three to four days longer in the second year than in the first. Further investigation revealed many inconsistencies, however, so the daily temperature range alone could not have been responsible for the main difference between the two sets of data. The most likely explanation is that there was an experimental error in the temperature records for 1929, either a systematic difference of approximately 2.7° F. (1.5° C.) between the temperature recorded by the thermograph and that to which the puparia were exposed or an error in the calibration of the thermograph itself. The larvae from which the puparia were secured fed principally upon mango, but some were reared from orange, sweet lime, peach, and pomegranate. When comparisons were made in such a way as to eliminate the temperature factor, no difference in the duration of the puparial stage could be found.

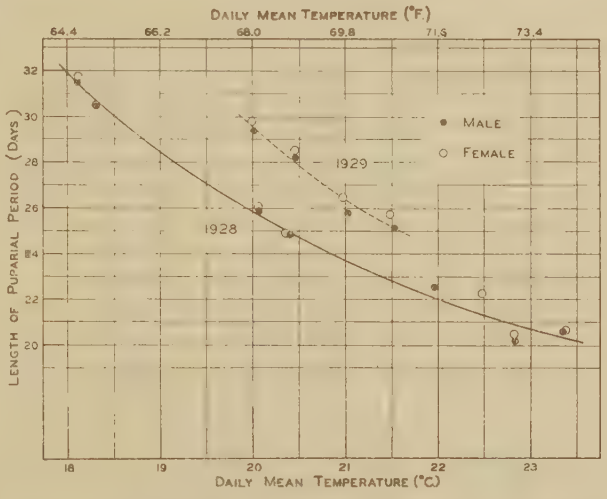

FIGURE 5.—Average length of the puparial period of male and female *Anastrepha ludens* plotted against average daily mean temperature in the insectary, Cuernavaca, Mexico

The two sexes emerged in nearly the same time, although the female regularly required somewhat longer than the male. The difference between them averaged 0.3 day, but was entirely consistent. The data for males and females have been plotted separately in Figure 5, although the same curves have been fitted to the values for both sexes.

Moisture did not seem to influence the rate of development within the puparium, but it did affect mortality. Though adult flies emerg-

[5] Personal communication.

ing in very dry containers were occasionally crippled, they were not so susceptible to injury as the newly formed puparia. In a preliminary experiment 850 puparia, which transformed on June 28, 1929, were placed in saturated sand in a large Petri dish and covered. Beginning the day following puparium formation, 50 individuals were transferred daily from the stock to empty open dishes, where they were kept until emergence. The experiment was performed during the rainy season. Table 9 shows the number of successful emergences. Since many of the pupae were parasitized by *Opius crawfordi* Vier., it was determined that the parasite as well as the host was most sensitive to drying during the first few days after puparium formation. The percentage of emergence of *A. ludens* has been plotted in Figure 6 on the assumption, from the results given in Table 16, that the mortality of the parasites was only 70 per cent as great as that of the flies.

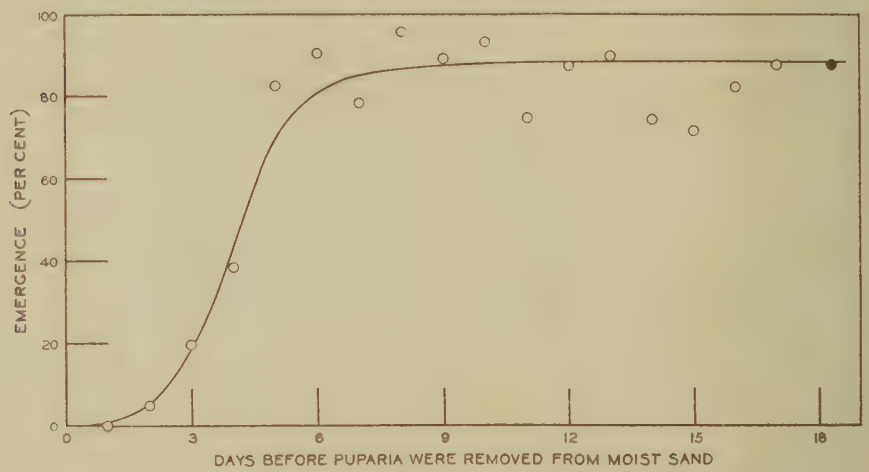

FIGURE 6.—Effect, upon survival of *Anastrepha ludens*, of the number of days after formation of puparium that the latter was transferred from moist sand to an open Petri dish in the insectary during the rainy season, Cuernavaca, Mexico, 1929. The puparia represented by the solid circle were left in moist sand throughout development

TABLE 9.—*Number of Anastrepha ludens and of its parasites emerging from lots of 50 puparia each when transferred to open dishes, free of soil, the indicated numbers of days after puparium formation, Cuernavaca, Mexico, 1929*

Insect	Number of insects emerging when transferred the day mentioned after formation of puparium																	
	1st	2d	3d	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	Check
A. ludens	0	2	8	15	32	35	28	38	39	37	29	32	33	28	30	31	33	33
Parasites	0	0	3	6	10	10	13	9	5	9	10	12	12	11	7	11	11	11

THE ADULT STAGE

As has been noted, mature larvae normally burrowed into the earth before forming puparia. They usually remained just below the surface, so that the adult fly upon emerging had to penetrate not more than an inch or two of soil. The greater this distance the higher was the mortality, other factors being equal. Several attempts were made to test the effect of depth of burial upon the per-

centage of adults emerging successfully, but with indifferent results. The contact surface of the soil with the walls of the containers probably introduced the greatest error by providing an easier route of exit for the flies. This difficulty was least pronounced in a field experiment started during the dry season, on January 16–18, 1929. Infested mangoes that were nearly ready to drop or had already fallen to the ground were buried in cloth sacks several miles from any known infestation, half of them in the sun and the other half shaded by a piece of cloth placed horizontally. The sacks, 24 inches in diameter, were filled with 3 inches of soil; 10 mangoes were then placed in the center of each sack and covered to a specified depth of 1 to 18 inches, 10 sacks being placed at each depth so that the soil on top of the mangoes was level with the surface of the ground. The mangoes, 600 in all, appeared from external examination to be nearly equally infested. The total emergence from each depth in the sun and in the shade is given in Table 10. These depths, of course, represent only the amount of soil over the mangoes, not the distance that the adult flies traversed in emerging.

TABLE 10.—*Number of adult Anastrepha ludens emerging from infested mangoes buried in sacks at various depths, half of them in the sun, the rest shaded by a piece of cloth placed horizontally, Cuernavaca, Mexico, 1929*

Depth buried	Adults emerged		Depth buried	Adults emerged	
	In sun	In shade		In sun	In shade
Inches	*Number*	*Number*	*Inches*	*Number*	*Number*
1	151	235	12	2	17
3	62	95	18	2	8
6	12	97			
9	2	12	Total	231	464

From Table 10 several facts are observable. Even a shallow covering of earth (3 inches) reduced materially the number of flies emerging, and, in general, the greater the depth of burial the greater was the reduction. Exposure to the sun reduced survival at all depths, but proportionately more at the greater depths, indicating an action by the sun principally upon the emerging adults rather than upon the buried fruit. Some flies emerged even at the greatest depth of 18 inches, but all of these were so badly crippled that they died soon afterwards; it is doubtful if they could have reached the surface at all had not the fruit been buried in sacks.

The time of emergence of flies issuing from puparia on the surface of soil in the insectary showed a marked diurnal fluctuation. Of 445 flies that emerged in April and May, 1928, 426, or 95.7 per cent, came out between 6 and 10 a. m. Exposure to sunlight and higher temperatures seemed to stimulate emergence. On the morning of August 3, on a shaded shelf in the insectary, the temperature ranged from 66.2° to 68.9° F. (19° to 20.5° C.) between 8.20 and 8.55 o'clock, while in the sun outside the insectary the thermometer read 82.4° to 87.8° F. (28° to 31° C.). A stock of puparia was transferred from the one condition to the other every 5 minutes for 40 minutes, with the results given in Table 11.

TABLE 11.—*Number of adults of Anastrepha ludens emerging from a stock of puparia which was exposed alternately to shade and sun for successive 5-minute periods, Cuernavaca, Mexico, 1928*

Adults emerging	Exposure ending at—								Total
	8.25 a. m.	8.30 a. m.	8.35 a. m.	8.40 a. m.	8.45 a. m.	8.50 a. m.	8.55 a. m.	9 a. m.	
In shade	2		4		6		0		12
In sun		39		29		13		1	82

Adult flies were not sexually mature when they emerged. The time from emergence to mating varied with the season and apparently with the average temperature. (Table 12.)

TABLE 12.—*Length of period from emergence of adult Anastrepha ludens to first mating for isolated pairs in small cloth-screened cages, Cuernavaca, Mexico*

Dates	Mean temperature		Cases	Length of period		
				Mean	Minimum	Maximum
1928	°F.	°C.	Number	Days	Days	Days
Apr. 19 to May 4	75.6	24.2	8	10.6±0.5	8	15
July 24 to Sept. 1	68.5	20.3	8	25.0±1.3	17	34
1929						
Jan. 3 to Feb. 6	67.3	19.6	14	23.1±1.0	14	33
Mar. 16 to Apr. 12	[1]71.4	[1]21.9	12	16.6±1.0	9	27
Mar. 31 to Apr. 22	72.3	22.4	12	13.2±0.8	9	22

[1] Exclusive of temperatures for Mar. 16 to 20.

Sexual maturity as determined by the first mating may have been delayed in some cases by the confinement of single pairs in small cages. A cage about 50 to 60 times as large (3½ cubic feet capacity) contained many pairs which emerged on August 3, 1928. A pair in the act of mating was observed on August 13 and on August 14, and four pairs on August 18, only 10 to 15 days after emergence. The minimum time for similar pairs in the small cages was 17 days, and the average 25 days. The males apparently reached sexual maturity several days earlier than the females that emerged at the same time, for they attempted mating sometimes 10 days before the females would consent. However, fertilization of the female was not required to initiate oviposition. Of 21 females studied during March and April, 1929, 2 laid eggs before they were observed to mate, and 5 others showed the typical oviposition response prior to mating but without laying any eggs. In these cases, however, the first mating generally followed in a day or less, and in only one case more than two days later.

Mating occurred in the cages at Cuernavaca only in the late afternoon and early evening, usually between 6 and 7 p. m. It frequently lasted for some time; pairs have been observed to remain united from 20 minutes to 3¼ hours. Pairs in cages mated at intervals throughout their lives, in one case as many as nine times, although the males showed sexual excitement oftener than the females would permit mating. In no case, however, was there any pitched battle between male and female such as Crawford described. In none of the writers' experiments could the death of the male be attributed to the female.

The female fly normally deposited her eggs beneath the skin of the mango without leaving an oviposition puncture that was visible to the naked eye. This made it quite difficult to secure satisfactory records on oviposition, especially since most field-collected mangoes

were already infested. Two methods were used. In the first method a whole mango was introduced into each individual cage from 9 to 10 a. m. and again from 5.30 to 7 p. m. and watched continuously. Following each oviposition it was removed and the position of the puncture marked. Later the time of observation was extended to three hours in the morning and four hours in the afternoon, but it then proved impossible to observe them daily throughout their lives. Aside from the greatly reduced time available for oviposition, the removal of the fruit immediately after the withdrawal of the ovipositor disturbed the female considerably, so that the results with this method were quite erratic. The second method, which superseded the first, reduced the exposed surface of fruit to a small section which could be examined without difficulty under magnification. A mango was tied against the celluloid back of the cage over a hole 1.5 cm in diameter, so that it was necessary to examine only a small portion of fruit for eggs.

Egg laying began very shortly after mating. Eight females which emerged April 19, 1928, laid their first viable eggs from 1 to 8 days after mating, the average being 4.2 ± 0.6 days. These individuals were handled by the first technic; they did not start egg production as soon as those that were handled by the second method. Of 10 females which emerged on March 16, 1929, 1 did not begin laying until 19 days after she mated. The remaining 9 laid viable eggs from 1 to 7 days after mating, the average being 3.3 ± 0.5 days. Similarly, 1 female among 11 which emerged March 31 and April 1, 1929, laid no fertile eggs until 11 days after she had been fertilized, although the remaining 10 produced viable eggs in 1.5 ± 0.3 days, some of these the same day they were fertilized, the latest one 5 days thereafter.

Once begun, the production of fertile eggs continued for a month or longer in the case of 13 of 34 females which emerged during the late winter or spring. One of these, which emerged on April 19, 1928, laid viable eggs from May 6 to July 2, inclusive, a period of 57 days, or until 74 days after emergence. The span of viable egg deposition for two of the flies transforming on February 18, 1929, was 47 and 50 days, or until 72 and 79 days after emergence. Two adults that appeared on March 16, 1929, produced viable eggs for 41 and 42 days (56 and 64 days from March 16), and the latter female was still laying when the experiment was discontinued on May 26. These individual flies, as indicated above, were prolific for a considerably longer period than the average female observed in these experiments.

From the standpoint of reproduction only fertile eggs would be of importance, but many eggs failed to hatch, and at other times females inserted their ovipositors in the fruit without depositing any eggs at all. Occasionally these responses preceded mating, so that oviposition behavior, as distinguished from reproduction, did not seem to require the stimulus of living sperm in the sperm receptacle of the female. Oviposition may be considered, therefore, in relation to the female and without special reference to the frequency of mating. The percentage of eggs that hatched did not depend upon the number of eggs in a single puncture, and in many batches some eggs hatched and some did not; so failure of an egg to develop ordinarily could not be attributed to conditions following deposition. The proportion of viable eggs varied with the season of the year, but was generally largest when oviposition activity was greatest.

The data on oviposition have been summarized in Table 13.

TABLE 13.—*Oviposition activity of Anastrepha ludens when single pairs were confined in small cloth-screened cages, Cuernavaca, Mexico*

WHOLE FRUITS INTRODUCED FOR SHORT PERIODS

Dates	Mean daily temperature [1]		Females	Length of period						Total oviposition punctures			Total eggs laid per female		
				Preoviposition			Oviposition								
				Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
1928															
	°F.	°C.	Number	Days	Days	Days	Days	Days	Days	Number	Number	Number	Number	Number	Number
Apr. 19 to Aug. 4	71.8	22.1	8	11.1±0.5	9	14	47.4±6.3	14	95	42.1±5.6	23	92	115±21	31	292
1929															
Jan. 3 to Mar. 12	68.7	20.4	9	24.6±1.4	16	33	[2](39)			[2](17.6)			[2](38.9)		
SMALL PORTION OF FRUIT CONTINUOUSLY AVAILABLE															
1929															
Feb. 18 to May 12	72.7	22.6	8	24.6±2.8	14	50	37.4±4.4	18	69	17.1±1.5	6	27	87.6±15.5	20	217
Mar. 16 to May 23	72.9	22.7	10	21.3±1.5	14	35	30.4	7	46	19.7	5	42	143.9	14	401
Mar. 31 to May 19	73.0	22.8	8	13.6±0.5	12	18	23.2	5	36	14.4	7	32	133.0	24	300

[1] Mean temperatures only approximate in some cases, there being a gap in the temperature records from Mar. 5 to 20 and from May 21 to 23, 1929.
[2] The probable error of the mean has not been calculated in cases where the data were incomplete.

Of the six groups of females which were followed individually, only two series were carried through to completion, those emerging on April 19, 1928, and handled by the original technic, and those emerging on February 18, 1929, and studied by the improved method. The remaining four series were discontinued while some females were still ovipositing. One was so fragmentary that it has not been considered. In another, those emerging January 3 to 10, continuous observations were interrupted by three 5-day periods without records and finally terminated after a mean oviposition period of 39 days. To permit a rough comparison with other seasons of the year, values for the missing intervals have been interpolated from the preceding and following 5-day periods. Both of the other groups, emerging on March 16 and on March 31 to April 1, were interrupted on May 26, after mean oviposition periods of 30 and 23 days, respectively, when four females in each group were still actively reproducing. Because of the incompleteness of the data, the egg laying of the females summarized in Table 13 has been compared in Table 14 on a rate basis which minimizes this error. In this table ovipositions recorded later than the mean preoviposition period plus 40 days have been omitted, the separate entries for each female have been determined individually, and the data for the different females in a single group averaged.

TABLE 14.—*Oviposition rate of same pairs of Anastrepha ludens as in Table 13, for interval ending approximately 40 days after mean preoviposition period for each group, Cuernavaca, Mexico*

Date adults emerged	Mean oviposition temperature [1]		Oviposition punctures per day	Punctures with eggs	Average eggs per puncture [2]	Eggs which hatched
1928	°F.	°C.	*Number*	*Per cent*	*Number*	*Per cent*
Apr. 19	73.4	23.0	1.10	48	2.7	19
1929						
Jan. 3 to 10	70.7	21.5	.47	40	2.2	----------
Feb. 18 to 19	72.1	22.3	.52	63	4.4	46
Mar. 16	73.4	23.0	.74	77	6.2	56
Mar. 31 to Apr. 1	73.6	23.1	.74	87	8.4	62

[1] Mean temperatures apply to this 40-day period only, but in some cases are only approximate owing to a gap in the temperature record.
[2] Including all punctures.

The different indices to oviposition in Table 14 show that as the season progressed the females showed greater fertility, not in one characteristic alone, but in several. With an increase in the frequency of oviposition punctures, more eggs were laid in each puncture, more punctures contained eggs, and more of the eggs were fertile. Though the series of 1928 showed frequent ovipositions, egg production and fertility were low. This may be attributed to the difference in the technic of handling the pairs. There was a gap in the temperature record accompanying the 1929 experiments from March 4 to 20, and another from May 21 to 23. With these omissions the mean temperature during the 40 days following the mean preoviposition period increased with each succeeding set of females.

In 1929 a few females laid a relatively large number of eggs, only a small percentage of which hatched. One female laid 217 eggs, of which 10 per cent hatched; another, 151 eggs, of which 11 per cent hatched. The low viability in these cases may have been due to low fertility in the male.

There was little correlation between the time required for an oviposition and the number of eggs laid in 155 timed cases in 1928 ($r = 0.28 \pm 0.05$). Each batch totaled from 1 to 18 eggs, or an average of 5.4 ± 0.2 eggs, and required from 1 to 12 minutes, or an average of 3.0 ± 0.1 minutes, to lay.

The total length of adult life was dependent on external conditions. The addition of water to the cages with the flies (Darby's technic) more than doubled their length of life when they were fed on ripe mango, and greatly lengthened survival with other foods. Direct midday sunshine killed caged adults very quickly, so that the location of the cloth-screened cages of adults in the shaded insectary was an essential part of the technic. Adult activity in the field agreed with this response to light. During early morning and late afternoon hours in May, June, and July adults were seen frequently in the field, but during the midday hours they disappeared. Ripe mango supported adult life more than six times as long as green mango.

The determinations of longevity were made by two different methods. In the first experiments, in the summer of 1928, eight pairs were confined in each of four lantern-globe cages without water, and the length of life was recorded. Those fed on ripe guava lived 51.5 ± 4.0 days, those fed on ripe mango 45.0 ± 5.1 days, but those fed on green mango only 5.1 ± 0.1 days. Starved flies survived 3.0 ± 0.1 days. In the winter and spring of 1929 flies were placed in small cloth-screened cages, similar to those used in oviposition experiments, starting with five pairs and providing water and food for feeding but not fruit for normal oviposition. This series was later augmented from the pairs used in the oviposition studies. On two occasions some flies were killed by accident, and on June 10 the remaining flies were moved from Cuernavaca to Mexico City. When observations were discontinued, several males and a few females were still living 179 days after emergence. Exclusive of individuals that lived less than 100 days, *A. ludens* survived an average of 145 ± 4 days on ripe mango and 133 ± 2 days on ripe orange. On ripe guava and green mango records on the duration of adult life were more complete, so that all individuals could be included. On ripe guava 17 adults that emerged on April 5 lived 75 ± 4 days, while on green mango 27 adults that emerged on February 16 and on April 2 lived 19.1 ± 1.4 days.

PARASITISM

Parisitism was confined largely to *Opius crawfordi* Vier., which at times was very abundant. This species laid its eggs in infested mangoes by means of a long ovipositor. The fruit-fly larva, with egg or larva of the parasite inside, would complete feeding, leave the fruit, burrow into the ground, and form an apparently normal puparium. In the puparium of the fly the parasite then completed its feeding, pupated, and developed to the adult stage, the whole process requiring about a day and a half longer than the puparial stage of *A. ludens*. From puparia formed between July 26 and August 5, 1928, and raised in an incubator in Mexico City at a temperature of 71.6°–73.4° F. (22°–23° C.), the data of Table 15 were secured.

TABLE 15.—*Number of individuals of Anastrepha ludens and its parasite, Opius crawfordi, emerging as adults after various periods beginning with formation of fly puparium; infested mangoes collected in Cuernavaca, Morelos, and pupae reared in Mexico City, 1928*

Insect	Number of adults emerging in—								Total	Mean length of period between formation of puparium and emergence of adult, days
	19 days	20 days	21 days	22 days	23 days	24 days	25 days	26 days		
Fly	11	85	55	20	--------	1	--------	--------	172	20.51
Parasite	2	14	19	19	15	14	3	4	90	22.17

In the series of experiments from which these records were taken there was a considerable mortality, due in part to the dryness of the containers. The parasite seemed less susceptible to these adverse conditions than the fly. Out of 650 pupae, 134 died too early in development to show the presence or absence of parasitism, but 198 more died late enough in development (some while the adults were emerging) to permit making the distinction. In Table 16, showing parasitism and emergence for five successive 4-day periods, beginning July 20, 1928, two conditions may be noted: (1) After they had reached a stage sufficiently advanced so that the two species could be separated (at the termination of the experiment), the parasite was more resistant to the adverse experimental conditions than the fly; (2) the progressively decreasing percentage of parasitism as the larvae left the fruit indicated that the parasite attacked the nearly full-grown fly larva much more successfully than it did the less mature stages.

TABLE 16.—*Parasitism by Opius crawfordi and survival in puparia of Anastrepha ludens, Cuernavaca, Mexico, 1928*

Date when puparium was formed	Emerged				Dead in puparium			Parasitism (total late stages)
	Flies		Parasites		Fly pupae	Parasites	Early stages	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Number*	*Number*	*Per cent*
July 20–23	11	52.4	18	78.3	10	5	0	52.3
July 24–27	31	57.4	38	69.1	23	17	16	50.4
July 28–31	39	60.9	28	68.3	25	13	36	39.0
Aug. 1–4	93	62.0	25	73.6	57	9	42	18.5
Aug. 5–9	32	47.1	3	50.0	36	3	40	8.1

The percentage of parasitism varied during the year. Early in the mango season it was low, but toward the end of the season in June parasites were seen frequently in the field. Lots of puparia were secured periodically from the soil and from full-grown larvae which transformed shortly after they were cut from fruit. In one series these fruits were collected on the ground; in another series they were picked from the trees. The total emergence and the percentage of parasitism by *Opius crawfordi* in relation to the source of the material and the month in which it was collected are given in Table 17.

The increase in parasitism through the season was marked. The proportion of parasitized individuals was largest in May among larvae taken in tree-collected fruits, but in June the drops were more heavily parasitized. At this time most of the fruit had fallen to the ground, but to what extent it had been parasitized before it dropped was unknown. Since adult parasites were abundant upon fallen fruit at the end of the season, they were apparently either tree or ground dwelling forms, depending upon the location of the crop.

TABLE 17.—*Monthly parasitism of Anastrepha ludens by Opius crawfordi in relation to the source of the material, Cuernavaca, Mexico, 1929*

Month	Soil		Fruit on soil		Fruit on tree	
	Total emergence	Parasitism	Total emergence	Parasitism	Total emergence	Parasitism
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
April			2,734	1.4	1,794	1.6
May	1,482	8.4	1,626	10.8	1,432	17.7
June	1,500	21.0	1,597	27.8	1,660	14.2

In addition to *Opius crawfordi*, three other parasites have been reared from fruit-fly pupae: *Galesus* sp., *Eucoila* sp., and *Anthrax scylla* O. S. It has not been determined whether or not these were all primary parasites. Galesus apparently was a pupal parasite. It has been reared only from field-collected pupae, never from pupae that transformed in the insectary from field-collected larvae. Eucoila, however, has been reared from both types of material, so that it probably parasitizes the larval stage. It was not so frequent as Galesus, for of 1,500 successful emergences from pupae collected in the field on June 22, 8 were Eucoila and 13 were Galesus. Only two specimens of *A. scylla* were obtained, and they emerged from field-collected pupae.

SUMMARY

Observations on the Mexican fruit fly (*Anastrepha ludens* Loew) were conducted during parts of two seasons in the heavily infested region in and about Cuernavaca, Morelos, south of Mexico City. In this locality *A. ludens* bred most abundantly in mango. In smaller numbers it occurred in sweet lime, orange, peach, and pomegranate, and occasionally in guava, but because of the frequency of off-season mangoes, none of these was an essential alternate host. Guavas were infested normally by the Central American fruit fly (*A. striata* Schin.), a species that seldom occurred in other fruits. The population of this species increased during the rainy season, when most guavas were in fruit, to a maximum in November and December. A third species, the West Indian fruit fly (*A. fraterculus* Wied.), occurred in smaller numbers almost entirely in the yellow mombin, or native "plum."

A comparison of weather conditions at Cuernavaca with those in citrus regions of the United States showed a precipitation most nearly resembling that in central Florida and a monthly mean temperature much more uniform than in the areas with which it was compared.

In field tests with sticky fly paper and in cage experiments containing several kinds of fruit, adult *Anastrepha ludens* showed less preference

for its characteristic host while feeding than when ovipositing. *A. ludens* preferred ripe mango (84 per cent) to green mango (16 per cent) for feeding, but green mango (95 per cent) to ripe mango (5 per cent) for oviposition. It reacted similarly to ripe and green guavas.

Of 1,730 eggs, 1,726 hatched within 6 to 10 days of deposition, depending principally upon the mean temperature. There was no perceptible difference in the length of development between eggs that were left in green fruit until nearly hatched and those that were removed immediately to a moist chamber.

Larvae reared in heavy laboratory watch glasses and fed with fresh mango transformed in an average of 25 days at a mean temperature of 70.5° F. (21.4° C.). The maximum larval period, 35 days, plus the egg stage agreed roughly with the maximum period for emergence from field-collected fruits, an interval of 41 and 44 days for two lots of fruit.

Within the maximum period in the fruit, the time of emergence was largely determined by environmental factors. Larvae left the fruit early in the morning; of 1,032 larvae, 92 per cent came out before 9 a. m. A correlation study showed that more larvae tended to emerge after cool nights than after warm ones. Exposure to a decreasing temperature produced emergence during the day when there was no emergence in checks under outdoor conditions. Rain falling directly on infested mangoes stimulated emergence to a marked degree, independently of time of day. Isolated rains, particularly after the fruits had been held under conditions unfavorable for emergence, caused an immediate exodus of most of the larvae in the fruits. Repeated exposure to daily rains reduced the period of emergence from mangoes by over one-half in comparison with that from protected fruits. Emergence was greater when mangoes were placed on wet than on dry sand. Puparium formation by full-grown or nearly full-grown larvae removed to glass dishes with mango pulp was delayed from 12 to 15 days by the absence of soil in the dish. Larvae ready for puparium formation avoided dry sand and burrowed in moist sand.

The length of the period within the puparium, comprising the prepupal and pupal stages, depended primarily upon temperature, lasting 32 days at 64.4° F. (18° C.) and 21 days at 73.4° F. (23° C.). Larval food had no effect upon length of development. The duration of the period differed slightly but regularly between the sexes, the female requiring 0.3 day longer than the male. Moisture did not seem to influence the rate of development, but exposure to drying during the first 5 days after puparium formation greatly increased mortality.

Adult flies normally emerged from the puparia just below the surface of the soil. When this distance was increased by burying infested fruits, the number of flies that emerged was reduced materially, and the greater the depth the greater was the reduction. Exposure to the sun reduced emergence for burial at all depths. Emergence of adults from puparia on the surface of the soil showed a marked diurnal fluctuation, 96 per cent emerging between 6 and 10 a. m.

Adult flies reached sexual maturity, as judged by the first mating, in an average of 11 to 25 days after emergence, depending upon the season, the temperature, and, under confinement, the type of cage. Males reached sexual maturity a little earlier than females which emerged at the same time, but the females occasionally oviposited before mating. In Cuernavaca mating occurred about dusk and lasted

from 20 minutes to over 3 hours. Caged pairs mated at intervals throughout their lives.

The deposition of viable eggs began ordinarily a few days after the first mating and frequently continued for a month or longer. In the experimental cages many eggs failed to hatch, while at other times a female would insert her ovipositor without laying. When the rate of oviposition for 40 days after the mean preoviposition period was observed, females which emerged between January 3 and April 1, 1929, showed as the season progressed an increase in the following criteria: Number of oviposition punctures in a day, from 0.47 to 0.74; the percentage of punctures with eggs, from 40 to 87; average number of eggs laid in such puncture, from 2.2 to 8.4; and percentage of eggs which hatched, from 46 to 62. During this interval of increasing fertility in the female, the mean temperature rose from 70.7° to 73.6° F. (21.5° to 23.1° C.). In 155 timed ovipositions an average of 3 minutes was required to lay 5.4 eggs, and the time during which the ovipositor was inserted was but slightly correlated with the number of eggs laid.

The length of adult life was quite dependent on external conditions. Caged individuals lived longer on ripe mango, ripe orange, and ripe guava than on green mango. The presence of water in the cage more than doubled longevity in most cases. Direct midday sun killed caged individuals quickly. Length of life under favorable conditions exceeded three months, and some individuals were still alive after six months, when experiments were discontinued.

Parasitism was confined largely to *Opius crawfordi* Vier., which laid its eggs in the infested mangoes. Parasitized larvae formed apparently normal puparia, from which adult parasites emerged about a day and a half later than did unparasitized flies. The parasite seemed to attack older larvae of *A. ludens* more successfully than younger ones. The percentage of parasitism varied with the season, increasing rapidly as the mangoes ripened, from 1.4 per cent in April to 27.8 per cent in June in dropped fruits. Three other parasites have been reared from fruit-fly pupae in small numbers: *Galesus* sp., *Eucoila* sp., and *Anthrax scylla* O. S.

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